TOPEX Side B Sigma0 Calibration Table Adjustments:
February 2001 Update

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revised 15 February 2001
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Introduction
The TOPEX ground processing system at the Jet Propulsion Laboratory (JPL) includes a sigma0 Calibration Table (the Alt_Calpars file in JPL's designation, but often here referred to as the Cal Table) which allows the sigma0 to be corrected by different factors for different data cycles. The Cal Table values are changed as a result of observed drifts in the TOPEX altimeter's power estimation. We report here the Cal Table values used in producing the geophysical data record (GDR) for Side B operation which began with TOPEX cycle 236. We also report our current estimate of a revised Cal Table, and a set of small adjustments which can be added to the GDR backscattering cross-section (sigma0) estimates to produce the sigma0 which would have been in the GDR if the revised Cal Table had been used in the GDR processing. This report covers TOPEX cycles 236-305.

An earlier version of this report, covering cycles 236-298, was issued on 7 November 2000. This February 2001 report is a replacement and update of the earlier version and covers cycles 236-305. We include the month and year in the title of this report in anticipation of future report updates, as needed, and we warn the reader that the revised Cal Tables may have further small changes in future updates. A final report containing final Cal Table values will be issued after the end of all TOPEX data acquisition operations.

TOPEX internal calibration modes
As in all recent spaceborne radar altimeters, TOPEX has an internal calibration mode with two submodes called Calibration Mode 1 and Calibration Mode 2. These will be referred to simply as Cal 1 or Cal 2 for convenience. In Cal 1 the altimeter tracks a small portion of its own transmitted pulse and makes both a range and a power estimate. In Cal 2 the altimeter looks at the receiver's noise level without any transmitted pulse present. There are two TOPEX calibration modes executed each day and we keep a database of these calibration measurements; specifically we record the changes in the Cal 1 and Cal 2 measurements from arbitrary reference values selected early in the altimeter's operation. Prior to launch we had expected that a drift in the TOPEX power estimation, hence in its estimation of the sea surface's radar backscattering cross-section sigma0, would be correctable by the observed drift in Cal 1 AGC. That does seem to be correct for Side B, but not for Side A as discussed in the next section.

Brief review of Side A corrections

In TOPEX Side A there were indications that the time trend of the Cal 1 AGC differed from the time trend of the over-ocean cycle-averaged sigma0 in both the Ku- and the C-band systems. We were forced to use the time trend of the over-ocean sigma0 cycle-averages to produce the sigma0 Cal Table entries. We tried to make these corrections only for relatively long times, avoiding responding to cycle-to-cycle noise. We also imposed a quantization on the Cal Table entries, making changes only of 0.03 dB (or multiples thereof). Correcting a noisy process by making trend estimates projections was a frustrating activity at best, and the Side A Cal Table had several places where we failed to detect trend changes or to correct our trend projections soon enough. After TOPEX was switched to Side B in early February 1999 we described the Side A Cal Table history in "TOPEX sigma0 calibration table history for all Side A data", G.S. Hayne and D.W. Hancock III, 27 July 1999, available at http://topex.wff.nasa.gov/docs/Sigma0Cal_A_All.pdf . In that paper we produced our best estimate of a revised Side A Cal Table based on a quadratic trend fit to the entire Side A set of over-ocean cycle-averages of sigma0.

Initial corrections in Side B

When Side B was turned on, we continued what we had been doing for Side A. Initial Side B Cal Table entries were set by a committee process, headed by P. S. Callahan (JPL's TOPEX Measurement System Engineer), so that there was no discontinuity in sigma0 from Side A to Side B. These initial values were held constant for a while until trends became apparent.

The Side B C-band Cal Table values were changed beginning with cycle 248 to correct for an apparent downward trend in the C-band over-ocean sigma0 cycle averages. No corrections were made to the Side B Ku-band Cal Table until cycle 259 when it became clear that there was an upward trend in the Ku-band over-ocean sigma0. Both the Ku- and the C-band Cal Table values were produced by assuming a linear time trend in the sigma0. The Ku-band system was particularly surprising in showing an increase in sigma0 estimates before correction.

Eventually it became clear that the linear trends in the Cal Table were over-correcting the data, and we decided to hold the Cal Table values constant until the data trends caught up with the correction; this Cal Table freeze was made at cycle 274 for Ku-band and at cycle 278 for C-band. After another ten cycles of data however, a decision was made to replace the Cal Table values from cycle 277 forward by values based on linear trends estimated from cycle 257 through about cycle 287, and to reprocess and re-release the TOPEX GDRs for cycles 277 - 287. An additional trend adjustment was made for data starting with cycle 302.

In all of the Side B Cal Table work we kept the same 0.03 dB quantization used in the Side A work. Table 1 summarizes the Side B Cal Table values for cycles 236-305. Column 1 of Table 1 is the data cycle number, and columns 2 and 3 give the Ku- and C-band Cal Table values which were used in producing the TOPEX GDR data product.

Current status of Side B power measurements

Figure 1a is a somewhat busy figure summarizing the Side B Ku-band altimeter's Cal 1, Cal 2, transmit power monitor, and over-ocean sigma0 cycle averages for cycles 236 - 305, and Figure

1b presents the corresponding information for the C-band altimeter. A small seasonal correction, derived from the entire set of Side A sigma0 data, has been applied to the over-ocean sigma0 averages. Notice that the Cal Table corrections have been removed from the over-ocean sigma0 in these figures, because our purpose is to see the trends in absence of Cal Table corrections. In Figures 1a and 1b the Cal 1 delta AGC trend is in quite good agreement with the over-ocean sigma0 trend, suggesting that the Cal 1 AGC change would provide an adequate basis for the Side B Cal Table (unlike the Side A altimeter where the Cal 1 trend differed from the over-ocean sigma0 trend).

Another effect visible in Figure 1a is an apparent step-change in both the Ku-band Cal 1 and the Ku-band over-ocean sigma0. This step occurred at cycle 256 which was a SSALT cycle during which a satellite safe hold occurred with the result that the TOPEX altimeter was powered off during most of cycle 256. During a normal SSALT cycle the TOPEX altimeter is still powered but is in its idle mode. We don't know why but the TOPEX altimeter behaves differently before and after this cycle 256 event. There is a visible step-change seen in Figure 1a, and we also observed a change in the Ku-band altimeter's track acquisition behavior in land-to-water transitions. Before cycle 256 there were occasional cases of the Ku-band altimeter's requiring several tens of seconds for acquisition, but after the cycle 256 safe hold the Ku-band land-to-water track transitions no longer show the occasional anomalous long acquisition times. For whatever unknown reason, the Side B altimeter behaves differently after the cycle 256 safe hold. The C-band altimeter Figure 1b shows less magnitude of effect than the Ku-band Figure 1a, but there does appear to be a small C-band step change at cycle 256 in Figure 1b.

Figure 1b shows the C-band transmitter power apparently decreasing about 0.2 dB, but the Cal 1 AGC changing by only 0.1 dB over the Side B history to date. We suspect that this is the result of an aging effect in the C-band transmitter power monitor, and not a real transmitter power change.

It is useful to ask if changes in altimeter temperature have to be considered in the sigma0 calibration. The short answer is no, based on the following observations. Figure 2 shows the AGC receiver section temperature, one of over two dozen altimeter internal temperatures which are collected from the telemetry stream, as a function of time. Figure 2a shows the entire TOPEX history of the AGC receiver section temperature, and Figure 2b shows only the Side B history of this temperature. The transition from Side A to Side B operation is clearly seen in Figure 2a, and it is expected that this Side B temperature would be different than the Side A. The Side B components are in different physical locations within the altimeter package on the spacecraft, and would be expected to have slightly different temperatures. Figure 2b clearly shows the temperature variations associated with the TOPEX changes to/from yaw steering. However, the Cal 1 and Cal 2 AGC data do not exhibit correlation with the observed temperature changes, and Figure 2b does not show any obvious temperature trends apart from the yaw steering effects. We have discussed the AGC receiver section temperature here, but the same lack of correlation with Cal 1 and Cal 2 AGC is found for all the telemetered TOPEX temperatures.

New Values for Side B Sigma0 Cal Table

At the time of about cycle 287 we decided to use the Cal 1 data as the entire basis for the Side B sigma0 Cal Table, based on the equivalent of Figures 1a and 1b at that time. We continue that assumption in this work. Instead of using the Cal 1 values directly to produce cycle-by-cycle Cal Table corrections, we chose to fit the Cal 1 data to a low order smoothing function, and base the Cal Table corrections on the fitted function. Cal 1 data from cycles 237-255 were fitted by least-squares straight line. A discontinuity was allowed at cycle 256. Then the data from cycles 258-305 were fitted by two connected straight line segments, with the transition point from one line to the other being one of the fitted parameters. This is an arbitrary choice of fitting function whose only justification is that "it looks reasonable". Perhaps with additional data the time trends will become clearer, and can be described in future report updates.

Figure 3a shows Ku-band Side B Cal 1 AGC and fitted line segments, and Figure 3b shows the same thing for C-band. The error bars shown in Figures 3a and 3b are estimated individual standard deviations of the 20 calibration mode results from which the cycle averages are formed, but in the least squares fit for the straight line segments the cycle means were equally weighted. The (negative of) Figure 3 data provide a relative correction, and it was arbitrarily decided to set the Cal 1-based corrections to zero at cycle 240; that is, we assumed that +0.45 dB was the correct Ku-band Cal Table value and +0.55 dB was the correct C-band Cal Table value at cycle 240. This allows us to calculate the values given in columns 4 and 5 of Table 1. These are our best current guess at the values which should have been in the Cal Table, and if one were to recalculate GDRs one should use the column 4 and 5 numbers as replacements for the values in columns 2 and 3 which were used in the original GDR production. Although we have consistently used 0.03 dB quantization in the Cal Table used in GDR production, there is no reason to be limited to this step size in Table 1's columns 4 and 5 and we have provided estimates to 0.001 dB. We do not believe the numbers are that good, and warn the user to apply his own realistic limits. A reasonable choice might be 0.01 dB.

In practical terms we can find "delta correction" values to be added to current GDR sigma0 values to produce the sigma0 values which would have been obtained if the ground processing had used Table 1's column 4 and 5 values instead of column 2 and 3. These delta correction values are given in columns 6 and 7 of Table 1, and are plotted in Figure 4. Figure 4 shows that the Ku-band sigma0 values for cycles 257 and 258 are most in need of additional adjustment. This is not surprising, given that no change in the Ku Cal Table was made from Side B start until cycle 259. The delta correction values are given to 0.001 dB, with the same warning as above.

Conclusion

We have reviewed the Cal Table values used in producing the currently distributed Side B TOPEX GDR sigma0 estimates, we have described our current best guess at what the Cal Table values should have been, and we provided a set of additive data correction values to be applied to the GDR sigma0. Columns 6 and 7 of Table 1 give these data correction values which are plotted in Figure 4. This work may be revised in future report updates, but we have given here our current best estimate at how to correct the Side B sigma0 data from cycles 236 through 305.

Figure 1a. Ku-Band Cycle-Average Cal 1 and Cal 2 Delta AGC and Sigma0 (Cal Table Corrections removed).

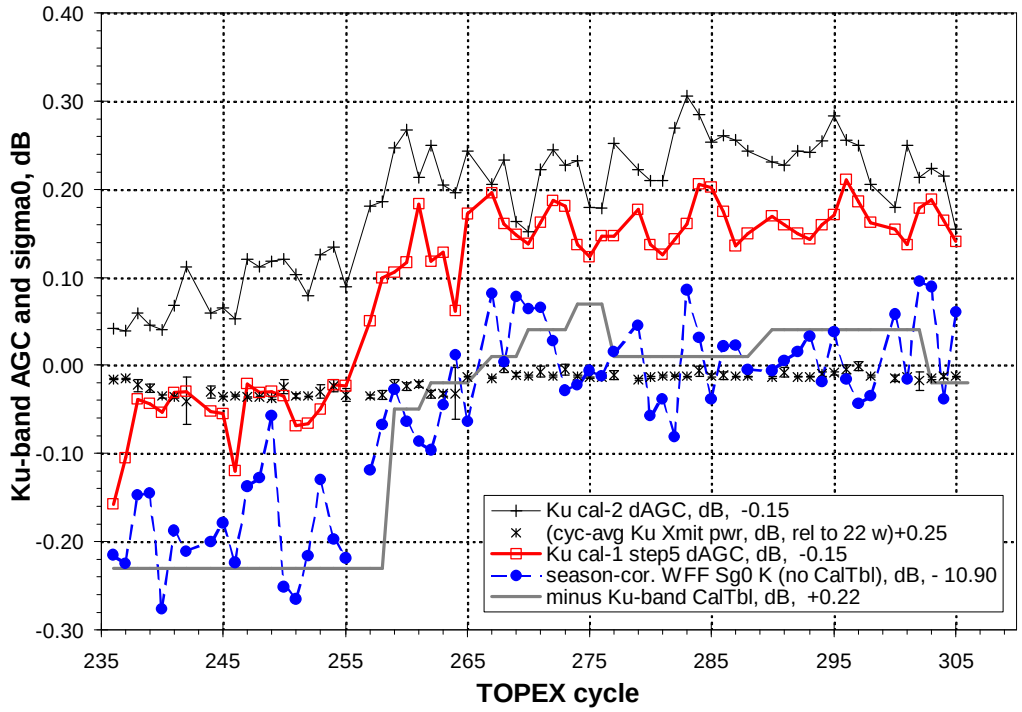

Figure 1b. C-Band Cycle-Average Cal1 and Cal2 Delta AGC and Sigma0 (Cal Table Corrections Removed).

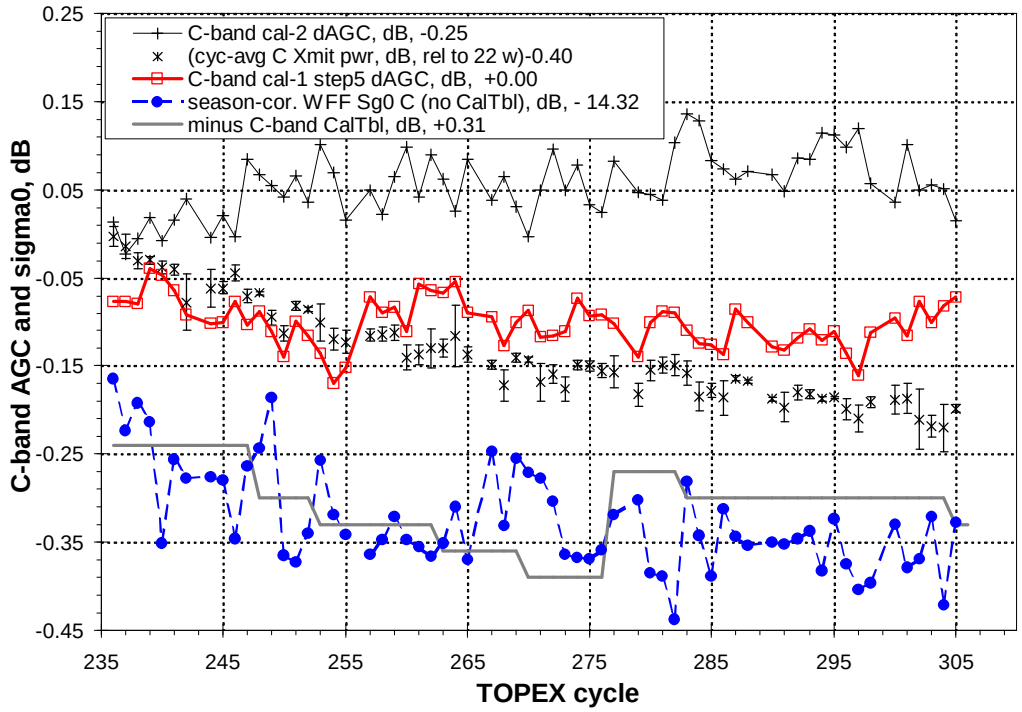

Figure 2a. TOPEX AGC Receiver Section Temperature *vs.* Cycle. Cycle 236 started Side B operation; triangles indicate SSALT cycles.

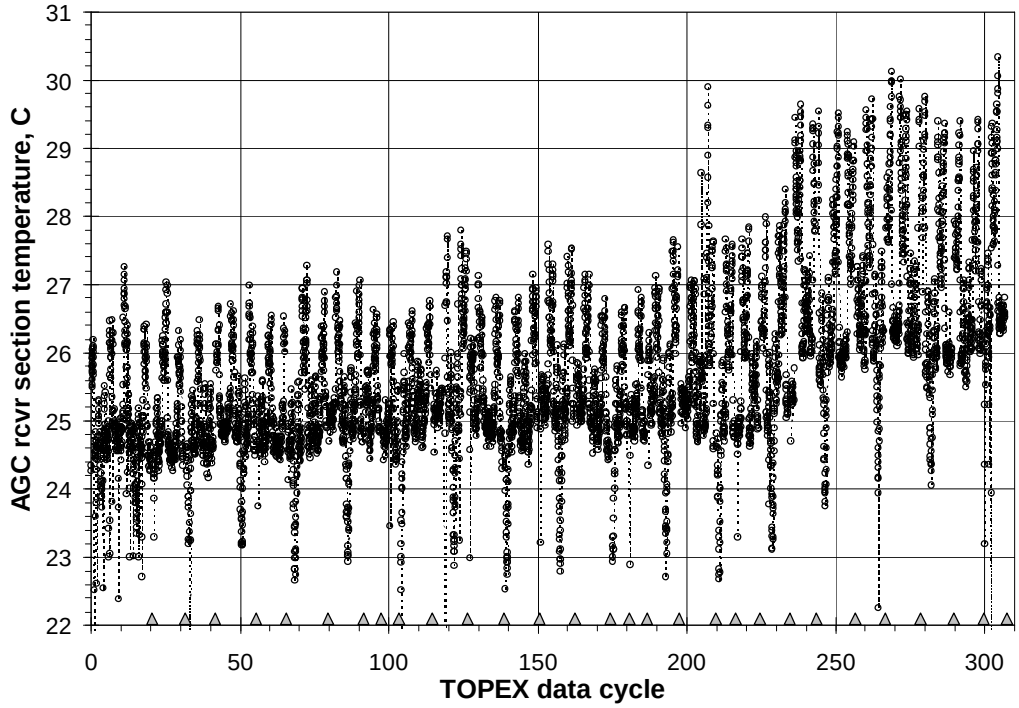

Figure 2b. Side B AGC Receiver Section Temperature *vs.* Cycle. Bottom triangles indicate SSALT cycles.

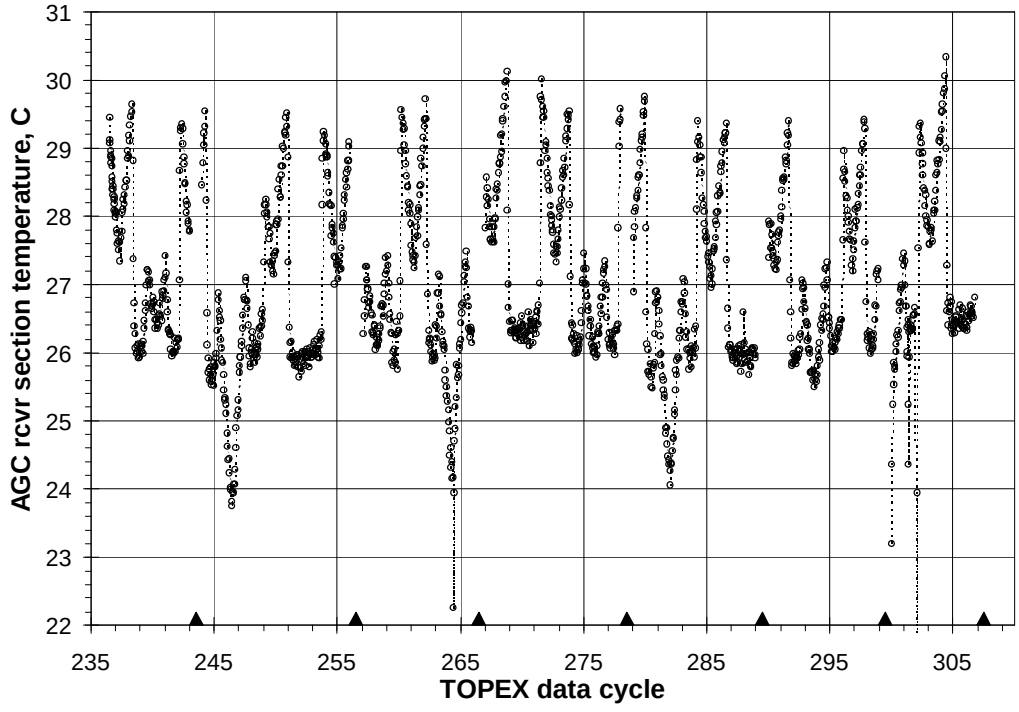

Figure 3a. TOPEX Side B Ku-Band Delta AGC *vs.* Cycle fitted by straight-line segments

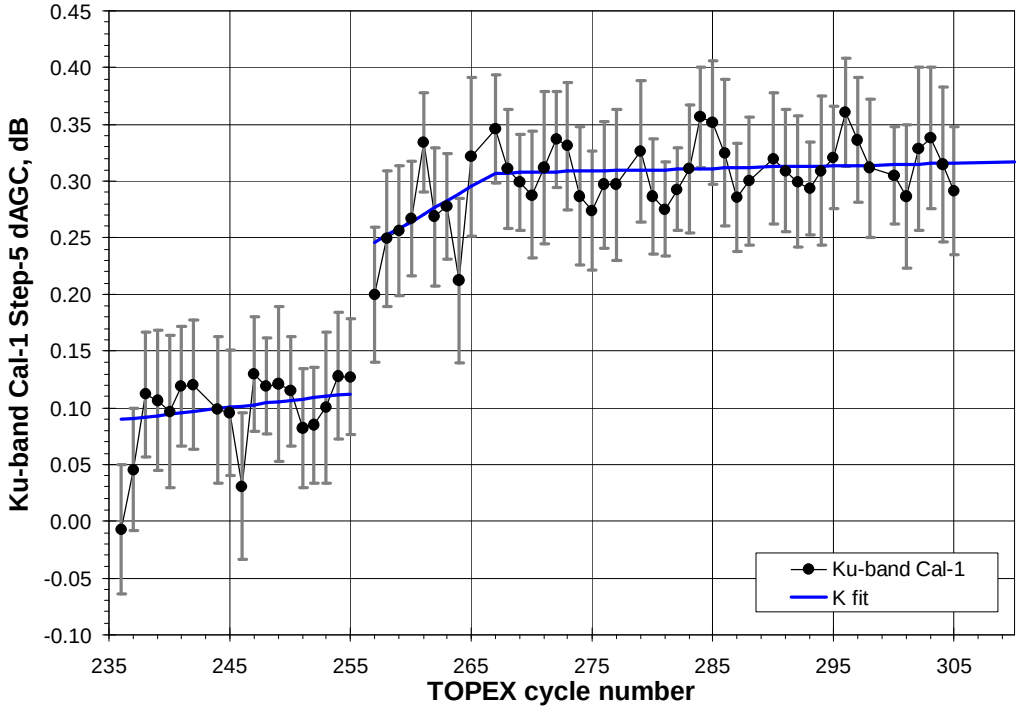

Figure 3b. TOPEX Side B C-Band Delta AGC *vs.* Cycle fitted by straight-line segments

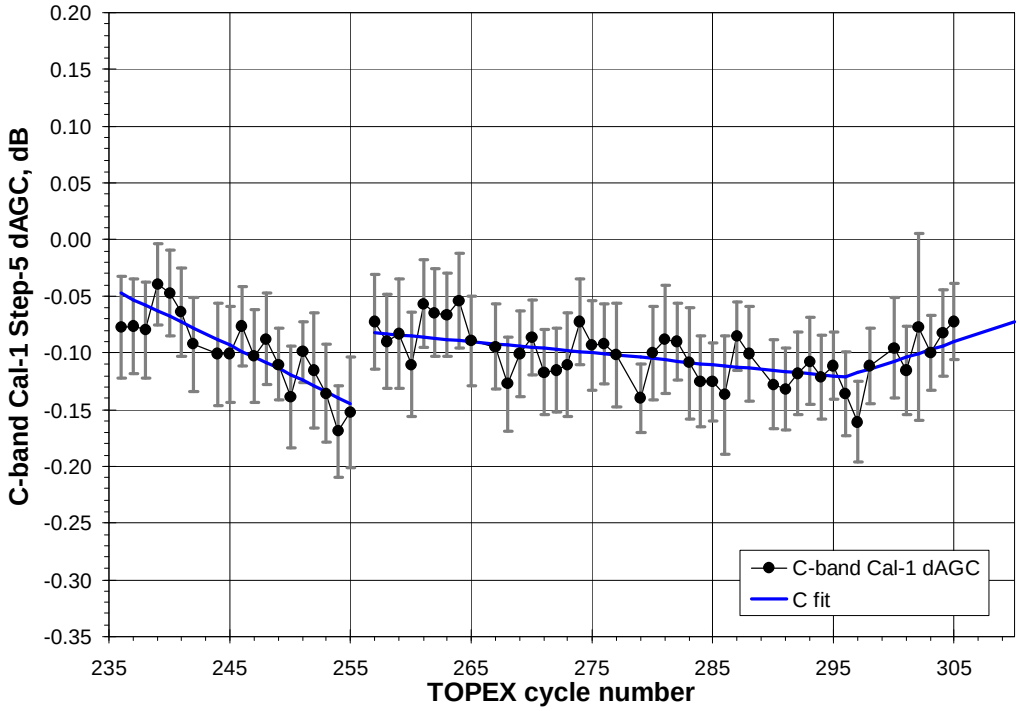

Figure 4. "Delta" Cal Table: Amount to be Added to GDR Sigma0 based on line-segment fit to Cal 1 AGC for cycles 237-305 (except 257)

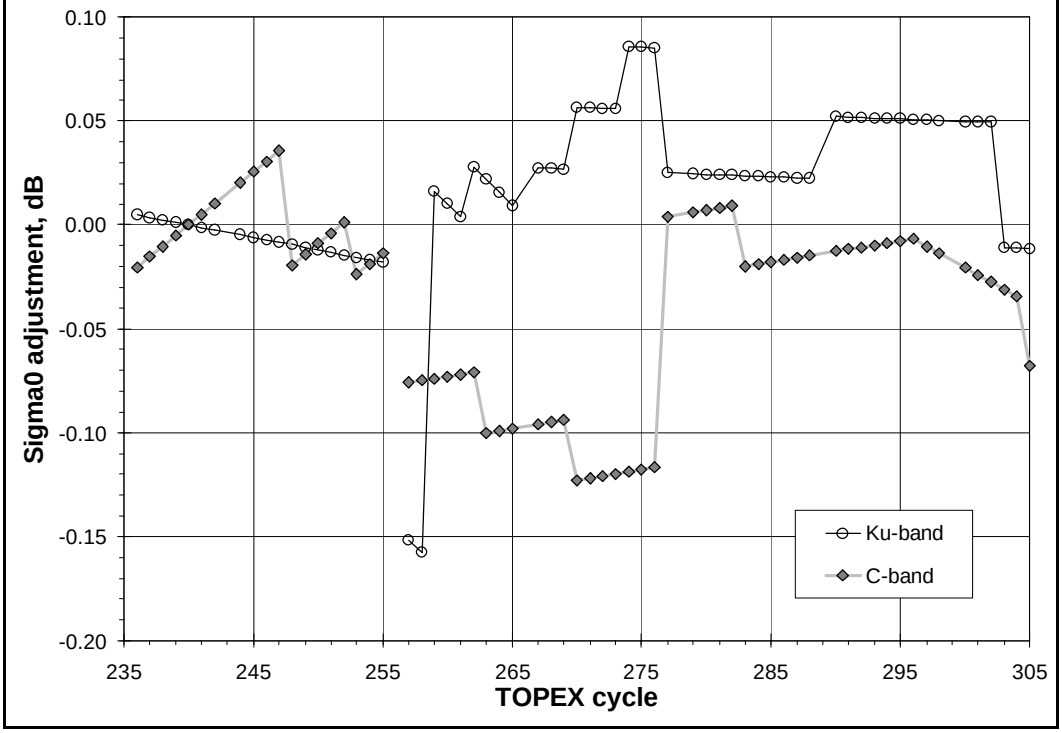

Table 1. TOPEX Sigma0 Cal Table Values, in dB, for cycles 236-305

col. 1	*col. 2*	*col. 3*	*col. 4*	*col. 5*	*col. 6*	*col. 7*
TOPEX Data Cycle	**Ku-Band Cal Table Value Used for GDR**	**C-Band Cal Table Value Used for GDR**	**Revised Ku-Band Cal Table Value**	**Revised C-Band Cal Table Value**	**Ku-Band Adjustment to GDR Sigma0**	**C-Band Adjustment to GDR Sigma0**
236	+0.45	+0.55	+0.455	+0.530	+0.005	-0.020
237	+0.45	+0.55	+0.454	+0.535	+0.004	-0.015
238	+0.45	+0.55	+0.452	+0.540	+0.002	-0.010
239	+0.45	+0.55	+0.451	+0.545	+0.001	-0.005
240	+0.45	+0.55	+0.450	+0.550	+0.000	+0.000
241	+0.45	+0.55	+0.449	+0.555	-0.001	+0.005
242	+0.45	+0.55	+0.448	+0.560	-0.002	+0.010
244	+0.45	+0.55	+0.445	+0.570	-0.005	+0.020
245	+0.45	+0.55	+0.444	+0.575	-0.006	+0.025
246	+0.45	+0.55	+0.443	+0.581	-0.007	+0.031
247	+0.45	+0.55	+0.442	+0.586	-0.008	+0.036
248	+0.45	+0.61	+0.440	+0.591	-0.010	-0.019
249	+0.45	+0.61	+0.439	+0.596	-0.011	-0.014
250	+0.45	+0.61	+0.438	+0.601	-0.012	-0.009
251	+0.45	+0.61	+0.437	+0.606	-0.013	-0.004
252	+0.45	+0.61	+0.436	+0.611	-0.014	+0.001
253	+0.45	+0.64	+0.434	+0.616	-0.016	-0.024
254	+0.45	+0.64	+0.433	+0.621	-0.017	-0.019
255	+0.45	+0.64	+0.432	+0.626	-0.018	-0.014
257	+0.45	+0.64	+0.298	+0.564	-0.152	-0.076
258	+0.45	+0.64	+0.292	+0.565	-0.158	-0.075
259	+0.27	+0.64	+0.286	+0.566	+0.016	-0.074
260	+0.27	+0.64	+0.280	+0.567	+0.010	-0.073
261	+0.27	+0.64	+0.274	+0.568	+0.004	-0.072
262	+0.24	+0.64	+0.268	+0.569	+0.028	-0.071
263	+0.24	+0.67	+0.262	+0.570	+0.022	-0.100
264	+0.24	+0.67	+0.256	+0.571	+0.016	-0.099
265	+0.24	+0.67	+0.249	+0.572	+0.009	-0.098
267	+0.21	+0.67	+0.237	+0.574	+0.027	-0.096
268	+0.21	+0.67	+0.237	+0.575	+0.027	-0.095
269	+0.21	+0.67	+0.237	+0.576	+0.027	-0.094
270	+0.18	+0.70	+0.237	+0.577	+0.057	-0.123
271	+0.18	+0.70	+0.236	+0.578	+0.056	-0.122
272	+0.18	+0.70	+0.236	+0.579	+0.056	-0.121
273	+0.18	+0.70	+0.236	+0.580	+0.056	-0.120
274	+0.15	+0.70	+0.236	+0.581	+0.086	-0.119
275	+0.15	+0.70	+0.235	+0.582	+0.085	-0.118
276	+0.15	+0.70	+0.235	+0.583	+0.085	-0.117
277	+0.21	+0.58	+0.235	+0.584	+0.025	+0.004
279	+0.21	+0.58	+0.235	+0.586	+0.025	+0.006
280	+0.21	+0.58	+0.234	+0.587	+0.024	+0.007
281	+0.21	+0.58	+0.234	+0.588	+0.024	+0.008
282	+0.21	+0.58	+0.234	+0.589	+0.024	+0.009
283	+0.21	+0.61	+0.234	+0.590	+0.024	-0.020

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col. 1	*col. 2*	*col. 3*	*col. 4*	*col. 5*	*col. 6*	*col. 7*
TOPEX Data Cycle	**Ku-Band Cal Table Value Used for GDR**	**C-Band Cal Table Value Used for GDR**	**Revised Ku-Band Cal Table Value**	**Revised C-Band Cal Table Value**	**Ku-Band Adjustment to GDR Sigma0**	**C-Band Adjustment to GDR Sigma0**
284	+0.21	+0.61	+0.233	+0.591	+0.023	-0.019
285	+0.21	+0.61	+0.233	+0.592	+0.023	-0.018
286	+0.21	+0.61	+0.233	+0.593	+0.023	-0.017
287	+0.21	+0.61	+0.233	+0.594	+0.023	-0.016
288	+0.21	+0.61	+0.232	+0.595	+0.022	-0.015
290	+0.18	+0.61	+0.232	+0.597	+0.052	-0.013
291	+0.18	+0.61	+0.232	+0.598	+0.052	-0.012
292	+0.18	+0.61	+0.232	+0.599	+0.052	-0.011
293	+0.18	+0.61	+0.231	+0.600	+0.051	-0.010
294	+0.18	+0.61	+0.231	+0.601	+0.051	-0.009
295	+0.18	+0.61	+0.231	+0.602	+0.051	-0.008
296	+0.18	+0.61	+0.231	+0.603	+0.051	-0.007
297	+0.18	+0.61	+0.230	+0.600	+0.050	-0.010
298	+0.18	+0.61	+0.230	+0.596	+0.050	-0.014
300	+0.18	+0.61	+0.230	+0.589	+0.050	-0.021
301	+0.18	+0.61	+0.230	+0.586	+0.050	-0.024
302	+0.18	+0.61	+0.229	+0.582	+0.049	-0.028
303	+0.24	+0.61	+0.229	+0.579	-0.011	-0.031
304	+0.24	+0.61	+0.229	+0.576	-0.011	-0.034
305	+0.24	+0.64	+0.229	+0.572	-0.011	-0.068